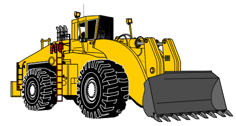
CHAPTER

1

INTRODUCTION

A. J. Clark School of Engineering •Department of Civil and Environmental Engineering



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ENCE 420 – Construction Equipment and Methods
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The Construction Industry

- The construction industry in the U.S. is a $400 billion industry.
- Over 1,145,000 contractors employing over 5 million people and utilizing heavy equipment.

The Construction Industry

- The industry is unique in several respects:
  - ***constructors*** (contractors) strive very hard to work themselves out of a job. The faster and better they perform, the sooner they will be looking for another project to build.
  - The products of construction are usually one-of-a-kind facilities, individually designed and built.
  - Construction is inherently a dangerous occupation, involving large and costly construction equipment.

Construction Contract

- An understanding of construction contracts is essential for the proper management of a construction project.
- Engineer/Architect contributes an important service in developing a contract.

Construction Contracts

Construction contracts must contain four legal items to be valid:

1. agreement (offer and acceptance)
2. consideration
3. capacity
4. legality

Construction Contracts

Agreement:

- There must be an ***agreement*** between the parties involved
- Such an agreement involves ***offer*** and ***acceptance***

The signed contract by the contractor constitute an **OFFER**

Notification by the owner of the winning proposal constitute **ACCEPTANCE**

Construction Contracts

Consideration:

• In the case of a construction contract, if a constructor promises to build an addition to a home without compensation and then changes his mind, he generally cannot be forced to build the addition because there was no *consideration* for his or her services.

Construction Contracts

Capacity:

This means that both parties must be of sufficient age to enter into a contract and mentally aware of what they are doing

Construction Contracts

Legality:

For a contract to be valid, it ***must be legal***. Obviously, a contract between two parties in which one agrees to commit an illegal act cannot be enforced!

Construction Contracts

General Types of Construction Contracts:

- Lump-Sum Contract (LSC)
- Unit-Price Contract (UPC)
- Cost-Plus-Fee Contract (CPFC)

Lump-sum Contract (LSC)

- In LSC contract, the owner will pay to the constructor an agreed-upon sum of money for the completion of a project conforming to a well-defined scope of work.
- This is the preferred type of contract for many construction services because the owner can obtain the benefits of competitive bidding and knows what the project will cost before he enters into a contract with a constructor.
- ***Effective*** lump-sum contracts can ***only*** be obtained if well-defined scopes of work are prepared in advance, which requires very careful and complete planning and scheduling.

Unit-price Contract (UPC)

- The owner will pay to the constructor an agreed-upon amount of money for each unit of work completed in a project. The units of work may be any items whose quantities can be determined (e.g. cubic yard of earth, lineal feet of pipe, etc..).
- Example:

	Quantity	Unit Price ($)	Sub-total
Piping	150	15	$2,250
Seeding	350 (sq. ft)	3	$1,050
Palm Trees	20	200	$4000
	Total		$7300.00

Unit-price Contract (UPC)

- Payments are usually made by the owner to the constructor at specified intervals with the amount of each payment depending on work actually completed during the prior period of time.
- This type of contract also requires a complete scope of work and is the preferred type of contract when the actual final quantities are not known with certainty beforehand.
- Under the terms of this contract the constructor may earn a profit or incur a loss, depending on the accuracy of his estimate per unit of work.

Cost-plus-fee Contract (CPFC)

- The owner will reimburse the constructor for all costs specified to construct the project, including all labor costs, material costs, equipment usage costs, subcontractor costs, and job supervision costs.
- The owner agrees to pay the constructor an additional fee, which is essentially a management fee, and to reimburse the constructor for the costs incurred at both his head and field offices resulting from the execution of the project.
- Under this type of contract the constructor usually takes the least risk, and therefore has the least incentive to keep costs down.
- It is used primarily in situations where the scope of work cannot be well defined ahead of construction or when the state of the art for the particular project is not well known.

Cost-plus-fee Contract (CPFC)

- To exercise some control and to give some incentive to the constructor to hold costs down, there are many variations to this type of contract, including:
  - **cost-plus-a-percentage-of-cost**,
  - **cost-plus-a-fixed-fee**, and
  - **cost-plus-a-sliding-fee**

  all with guaranteed maximums or with incentives to hold down the costs.
- CPFC contracts are complicated.

Performance Guarantees

- Constructors frequently are required to furnish a *performance bond* for each project.
- The bond is a three-party instrument in which a bonding company (termed *surety)* guarantees (or bonds) to the owner that the project will be built by the constructor in accordance with the contract.
- The cost of a performance bond depends on the size and risk of the contract and the reputation and expertise of the constructor.
- Good constructors who are constructing typical projects can obtain performance bonds for something less than l % of the project cost.

Constructor Specialties

- Constructors or contractors tend to specialize somewhat in various types of work.
- There are no clear-cut lines separating the fields of construction, they may be divided into:
  - Residential
  - Building-commercial
  - Industrial
  - Highway-heavy
  - Airport
  - Specialty work

Characteristics of Equipment-Intensive Operations

- The constructor works under a unique set of production conditions, which directly affect the selection of construction equipment.
  - A construction company carries its factory to each job site. At each site the constructor erects a construction plant specifically designed for that project.
  - The constructor has little opportunity for "fine tuning" of his construction process.
  - Construction projects are completed too fast, and lessons learned have limited applicability to future projects because of the one-of-a-kind nature of each construction project.

Risk Factors in Equipment-Intensive Work

- There are significant risks involved in utilizing construction equipment on jobs requiring large equipment-resource investment:
  - ***Earth and rock dam construction*** and canal work demand large concentrations of equipment. It is usually bid on a unit-price basis and can be subject to large variations between estimated and actual quantities.
  - ***Highway work***, often the least profitable of all heavy construction projects, frequently requires an equipment commitment that is greater than the gross contract value. Highway work is usually spread over several miles, making its control and management very difficult.

Risk Factors in Equipment-Intensive Work

- ***Airport construction*** requires a large equipment spread.
- ***Pipeline construction*** is the most volatile type of equipment-intensive work. Speed of pipeline work requires constructors to keep current on job costs and overruns.
- All types of construction share a critical dependence on the climate and the weather.

More Risk Factors in Equipment-Intensive Work

- Financing Mechanisms
- Government-initiated Construction Activity Levels
- Labor Regulations, Agreements, and Safety

Financing Mechanisms

- Contract payment retention provisions allow owners to retain substantial dollar amounts, which constructors have already earned, for long periods of time.
- Retainage shows as an asset on a constructor's books, it cannot be utilized for operation and growth and can cause serious cash flow problems.
- Most contractors consider cash flow to be the critical factor in any equipment decision.

Construction Economics and the Designer

- The cost of a project is determined by the requirements of the contract documents:
  – Prior to completing the final design, the engineer should give careful consideration to the method and equipment, which may be used to construct the project
  – Requirements, which increase the cost without producing equivalent benefits, should be eliminated
  – The decisions of the engineer should be based on a sound knowledge of the construction methods and equipment to be employed

Construction Economics and the Designer

- The budget for a project may be divided into six or more items:
  – Materials
  – Labor
  – Equipment
  – Subcontracts
  – Overhead, and
  – Profit/risk.

Construction Economics and the Designer

- *Examples of engineering practices that increase cost:*
  - Requiring materials that must be transported over long distances
  - Excessive testing
  - Not allowing substitution of equal-quality materials
  - Requiring many one-of-a-kind items which cannot be mass-produced
  - Using nonstandard materials or techniques when not required
  - Establishing standards of quality that are higher than necessary.

Construction Economics and the Designer

- Some ways to to reduce the costs of construction:
  1. Design concrete structures with as many duplicate members as practical.
  2. Simplify the design of the structure where possible.
  3. Design for the use of cost-saving equipment and methods.
  4. Eliminate unnecessary special construction requirements.
  5. Design to minimize labor-intensive activities.
  6. Specify a quality of workmanship that is consistent with required project quality.
  7. Furnish adequate subsurface information where possible.

Construction Economics and the Designer

8. Refrain from requiring the constructor to assume the adequacy of design or the responsibility for information that should be furnished by the engineer or architect.
9. Use local materials when they are satisfactory.
10. Write simple, straightforward specifications, which clearly state what, is expected. Define either the results expected or the methods of accomplishing the desired results, but not both.
11. When possible, use standardized specifications, which are familiar to the constructors.
12. Hold pre-bidding conferences with constructors in order to eliminate uncertainties.
13. Use inspectors who have sufficient judgment and experience to understand the project and to give them the authority to make decisions.

Construction Economics and the Contractor (Constructor)

- Most construction contractors work within a unique market situation.
- The job plans and specifications, which are supplied by the owner, will dictate the sales conditions and product, but not the price.
- The vast majority of work in the construction industry is awarded on a bid basis, through either open or selective tender procedures.
- The constructor states his price after estimating the cost, including his overhead, evaluating the risk, and adding a desired profit.
- Usually winning constructor has been able to underbid his competitors because of a more efficient work plan, lower overhead costs, or a willingness to accept a lower profit, and increased risk.

The Time Value of Money (TVM)

- Money has a time value
- One dollar today is worth more than $1 tomorrow
- Failure to pay the bills results in additional charge termed

The Interest (i)

- Interest is usually expressed as a percentage of the amount owed.
- It is due and payable at the close of each period of time involved in the agreed transaction (usually every month).

Example:

If $ 1,000.00 is borrowed at 14% interest, then interest on the ***principal of*** $ 1,000.00 after one year is 0. 14 x 1, 000, or $140.00.

If the borrower pays back the total amount owed after one year, she will pay $1,140.00.

If she does not pay back any of the amount owed after one year, then normally the interest owed, but not paid, is considered now to be additional principal, and thus the interest is ***compounded.***

*A*fter two years she will owe $1,140.00+0.14 X 1,140.00,or 1,299.60.

Equivalency

The banker normally does not care whether you pay him $1,140.00 after one year or $1,299.60 after two years. To him, the three values ($1,000, $1,140, and $1,299.60) are ***equivalent***.

$ 1,000 today is equivalent to $1,140 one year from today,

$ 1,000 today is equivalent to $1,299.60 two years from today.

The three values are not equal but *equivalent*.

Note:

1. ***The concept of equivalence involves time and a specified rate of interest***. *The* three preceding values are only equivalent for an interest rate of 14%, and then only at the specified times.
2. *Equivalence* means that one sum or series differs from another only by the accumulated interest at rate ***i*** for ***n*** periods of time.

Symbols

- To generalize the concept of interest the following symbols are used:

  P = a present single amount of money

  F = a future single amount of money, after *n* periods of time

  i = the rate of interest per interest period (usually one year)

  n = the number of periods of time (usually years)

Financial analysis

- Single payment
- Uniform series of payments
- Discounted present worth analysis
- Rate of return analysis

Single Payment Analysis

- To calculate the future value F of a single payment *P after n* periods at an interest rate *i*, we make the following calculation:

At the end of the first period: $F_1 = P + Pi$
At the end of the second period: $F_2 = P + Pi + (P + Pi)i = P(1 + i)^2$
At the end of the nth period: $F = P(1 + i)^n$

The future single amount of a present single amount is

$$F = P(1 + i)^n$$

Single Payment Analysis

Note:

F is related to *P* by a factor which depends only on *i* and *n*. This factor, termed *the single payment compound amount factor* (SPCAF), makes *F equivalent to P.*

SPCAF may be expressed in a functional form:

$$(1+i)^n = \left(\frac{F}{P}, i, n\right) \quad \text{or} \quad F = P\left(\frac{F}{P}, i, n\right)$$

The present single amount of a future single amount is

$$P = \frac{F}{(1+i)^n} \quad \text{or} \quad P = F\left(\frac{P}{F}, i, n\right)$$

Single Payment Analysis

Note:

The factor $1/(1+i)^n$ is called the *present worth compound amount factor* (PWCAF)

$$\frac{1}{(1+i)^n} = \left(\frac{P}{F}, i, n\right)$$

Example 1: Single Payment

- A contractor wishes to set up a revolving line of credit at the bank to handle her cash flow during the construction of a project.
  She believes that she needs to borrow $12,000 with which to set up the account, and that she can obtain the money at 1.45% per month.

  If she pays back the loan and accumulated interest after 8 months, how much will she have to pay back?

  $F = 12{,}000(1 + 0.0145)^8 = 12{,}000(1.122061) = 13{,}464.73 = \underline{\$13{,}465}$

  The amount of interest will be:

  $13,465 - 12,000 = $1,465.

Example 2: Single Payment

- A construction company wants to set aside enough money today in an interest-bearing account in order to have $ 100,000 five years from now for the purchase of a replacement piece of equipment.

  If the company can receive 8% interest on its investment, how much should be set aside now to collect the $100,000 five years from now?

  $P = 100{,}000/(1 + 0.08)^5 = 100{,}000/(1.46933) = \$68{,}058.32 = \underline{\$68{,}060}$

  To solve this problem you can also use the tables in Appendix A.

  $P = 100{,}000\ (P/F,\ 8{,}5) = 100{,}000(0.6805832)\ \$68{,}058.32 = \underline{\$68{,}060}$

Uniform Series of Payments

Analysis

- Often payments or receipts occur at regular intervals, and such uniform values can be handled by the use of additional functions.

  Another symbol:

  A = uniform ***end-of-period*** payments or receipts continuing for a duration of ***n*** periods
- If a uniform amount A is invested at the end of each period for *n* periods at a rate of interest *i* per period, then the total equivalent amount F at the end of the *n* periods will be:

$$F = A\left[(1+i)^{n-1} + (1+i)^{n-2} + \dots + (1+i) + 1\right]$$

By multiplying both sides of above equation by (1+*i*) and subtracting from the original equation, the following expression is obtained:

$$Fi = A(1+i)^n - 1$$

Uniform Series of Payments

Analysis

Which can be rearrange to give

$$F = A\left[\frac{(1+i)^n - 1}{i}\right]$$

The relationship can also be expressed in a functional form as

$$F = A\left(\frac{F}{A}, i, n\right)$$

[(1+*i*)^n - 1]/*i* is called the *uniform series compound amount factor* (USCAF)

It can also be shown that

$$A = F\left[\frac{i}{(1+i)^n - 1}\right]$$

Uniform Series of Payments Analysis

Which can be expressed in a functional form as

$$A = F\left(\frac{A}{F}, i, n\right)$$

The relationship $i / [(1+i)^n - 1]$is termed as the uniform series sinking fund factor (USSFF)

Recall that $$F = P(1+i)^n$$

Hence

$$P = A\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right] \quad \text{or} \quad P = A\left(\frac{P}{A}, i, n\right)$$

Uniform Series of Payments Analysis

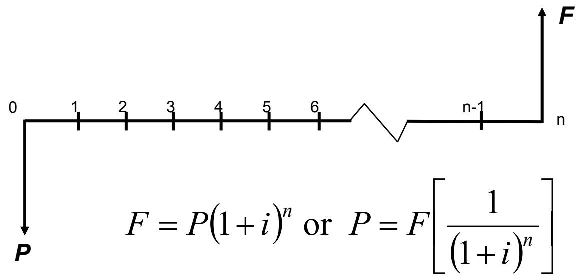
The relationship $\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right]$ is called the *uniform series present worth factor* (USPWF)

Also

$$A = P\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right] \quad \text{or} \quad A = P\left(\frac{A}{P}, i, n\right)$$

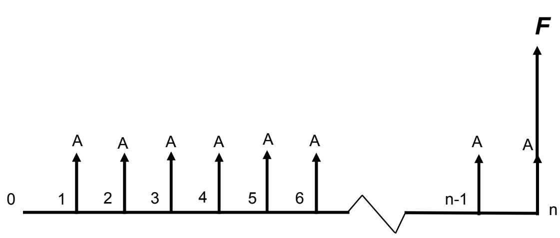
The relationship $\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right]$ is called the uniform series capital recovery factor (USCRF)

Cash Flow Diagram for Single Payment



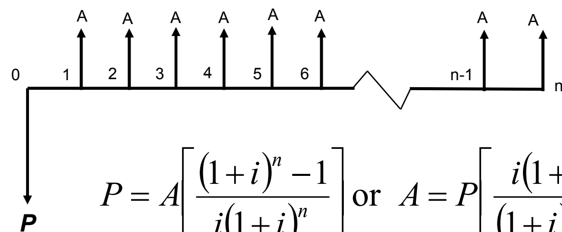
$$F = P(1+i)^n \text{ or } P = F\left[\frac{1}{(1+i)^n}\right]$$

Cash Flow Diagram for Uniform Series of Payments



$$F = A\left[\frac{(1+i)^n - 1}{i}\right] \text{or } A = F\left[\frac{i}{(1+i)^n - 1}\right]$$

Cash flow diagram for uniform series of payments



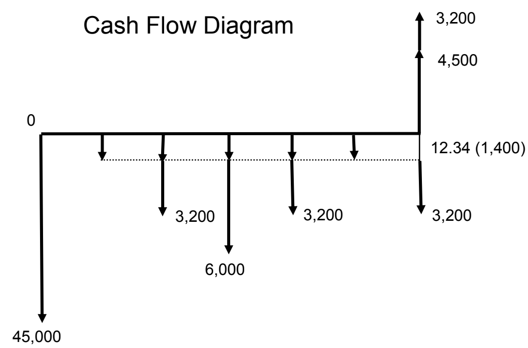
$$P = A\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right] \text{ or } A = P\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right]$$

Example 3

- A piece of construction equipment costs $45,000 to purchase.
- Fuel, oil, grease, and minor maintenance are estimated to cost $12.34 for each hour that the equipment is used.
- The tires cost $3,200 to replace (estimated to occur every 2,800 hours of use), and major repairs of $6,000 are expected after 4,200 hours of use.
- The piece of equipment is expected to last for 8,400 hours, after which it will have an estimated salvage value of 10% of the purchase price.

How much should the owner of the equipment charge, per hour of use, if he expects to use the piece of equipment about 1,400 hours per year? Assume an annual interest rate of 15%.

Example 3 (continued)



Example 3 (continued)

n = 8,400/1,400 = 6 years

A_1 = - 45,000(A/P,15,6) = - 45,000 (0.26424) = -11,890.80

A_2= - 12.34 (1,400) = -17,276.00

A_3= - 3,200 (A/F,15,2) = - 3,200 (0.46512) = -1,488.38

A_4= - 6,000 (P/F,15,3)(A/P,15,6)

= - 6,000 (0.65752)(0.26424) = -1,042.46

A_5= +(4,500 + 3,200) (A/F,15,6) = + 879.65

A_T= the total annual cost = -30,817.99

The hourly cost 30,817.99/1,400 = <u>$22.01/hr</u>

$$A = P\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right] \text{ or } A = P\left(\frac{A}{P}, i, n\right) \qquad A = F\left[\frac{i}{(1+i)^n - 1}\right]$$

$$P = A\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right] \text{ or } P = A\left(\frac{P}{A}, i, n\right)$$

Discounted Present Worth Analysis

- Often in engineering economic studies, as well as in general financial analyses, a discounted present worth analysis is made of each alternative under consideration.
- It involves calculating the *equivalent* present worth or present value of all the dollar amounts involved in the alternative to determine its present worth.

Definition:

The present worth is *discounted* at a predetermined rate of interest called the *minimum attractive rate of return* (MARR or i^*).

The MARR is usually equal to the current rate of interest for borrowed capital plus an additional rate for such factors as risk, uncertainty, and contingencies.

$$\text{MARR} = i^* = i + i(\text{risk})$$

Example 4

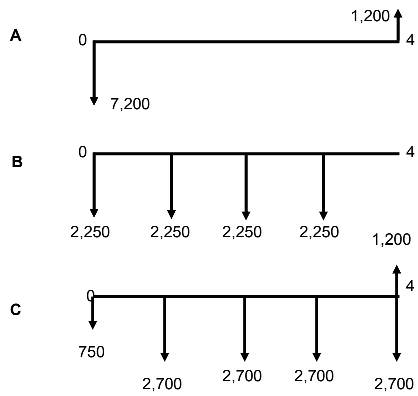
- The Ace-in-the-Hole Construction Company is considering three methods of acquiring company pickups for use by field engineers. The alternatives are:
  - **A.** Purchase the pickups for $7,200 each and sell after 4 years for an estimated $1,200 each.
  - **B.** Lease the pickups for 4 years for $2,250 per year paid in advance at the beginning of each year. The contractor pays all operating and maintenance costs on the pickups and the leasing company retains ownership.
  - **C.** Purchase the pickups on special time payments with $750 down now and $2,700 per year at the end of each year for 3 years. Assume the pickups will be sold after 4 years for $1,200 each.

If the contractor's MARR is 15%, which alternative should he choose?

Note: All alternatives involve equal lives.

Example 4 (continued)

To solve, calculate the net present worth (NPW) of each alternative at 15% and select the least costly alternative:



NPW_A = -7,200 + 1,200(P/F),15,4) = -$6,514

NPW_B = -2,250 - 2,250(P/A),15,3) = -$7,387

NPW_C = -750 - 2,700(P/A),15,4)+1,200(P/A),15,4) = -$7,772

The least costly alternative is A

What to do When Alternatives Involve Different Lives

Approach 1:

Truncate (cut off) the longer-lived alternative(s) to equal the shorter lived alternative and assume a salvage value for the unused portion of the longer lived alternatives. Then make the comparison on the basis of equal lives.

Approach 2:

Assume equal replacement conditions (costs and incomes) for each alternative and compute the discounted present worth on the basis of the least common multiple of lives for all alternatives.

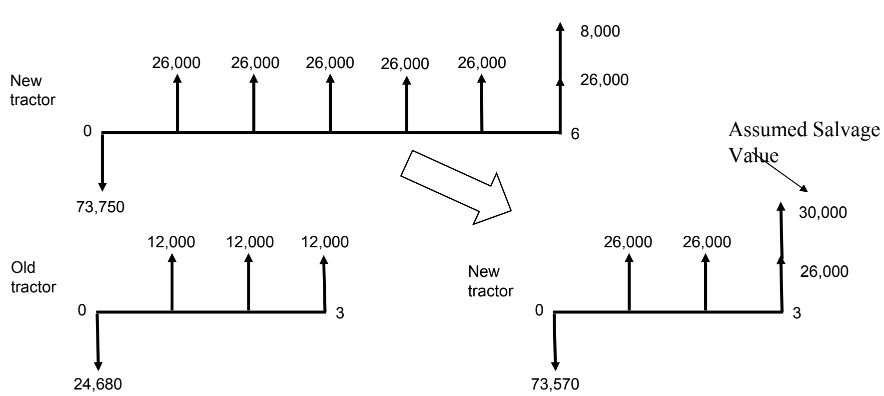
Example 5

- A contractor is considering the purchase of either a new track-type tractor for $73,570, which has a 6-year life with an estimated net annual income of $26,000 and a salvage value of $8,000, or a used track-type tractor for $24,680, with an estimated life of 3 years and no salvage value and an estimated net annual income of $12,000.

  If the contractor's MARR is 20%, which tractor, if any, should she choose?

Example 5 (continued)

Approach 1. ***(comparison on the basis of equal lives)***



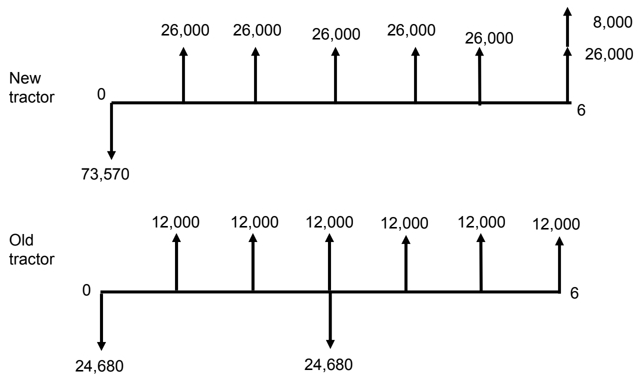
NPW_{new} = -73,570 + 26,000(P/**A**,20,3) + 30,000(P/**F**,20,3) = -73,570 + 26,000(2.10648) + 30,000(0.5787) = -$1,443

NPW_{old} = -24,680 + 12,000(P/A,20,3) = -24,680 + 12,000(2.10648) = + $597

Conclusion: Old tractor is a better Alternative

Example 5 (continued)

Approach 2. ***(comparison on the basis of equal replacement conditions)***



NPW_{new} = -73,570 + 26,000(P/**A**,20,6) + 8,000(P/**F**,20,6) = -73570 + 26,000(3.32551) + 8,000(0.33490) = -$15,570

NPW_{old} = -24,680 + 12,000(P/**A**,20,6) - 24,680(P/**F**,20,3) = -24,680 + 12,000 (3.32551) - 24,680(0.57870) = +$944

Conclusion: New tractor is a better Alternative

Rate of Return (ROR) Analysis

- Knowing the anticipated *rate of return* of an investment permits decision maker to have more "perceived" confidence in its decision!

Definition:
*The **rate of return*** of a proposed investment is that interest rate which makes the discounted present worth of the investment equal to zero.

- To calculate the *rate of return,* simply set up the equation to be equal to zero and solve for *i*.

Example 6

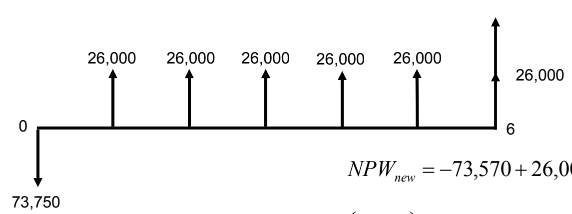
- A contractor is considering the purchase of either a new track-type tractor for $73,570, which has a 6-year life with an estimated net annual income of $26,000, or a used track-type tractor for $24,680, with an estimated life of 3 years and no salvage value and an estimated net annual income of $12,000.

  If the contractor's MARR is 20%, which tractor, if any, should be chosen?

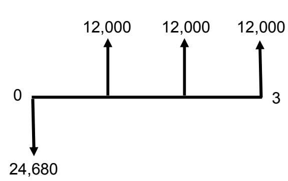
Example 6 (continued)

Approach 1. ***(comparison on the basis of equal lives)***

New tractor



Old tractor



$$NPW_{new} = -73{,}570 + 26{,}000\left(\frac{P}{A}, i, 6\right) = 0$$

$$\left(\frac{P}{A}, i, 6\right) = \frac{73{,}570}{26{,}000} = 2.82962 = \frac{(1+i)^6 - 1}{i(1+i)^6}$$

$$i_{new} = 26.9\%$$

$$NPW_{old} = -24{,}680 + 12{,}000\left(\frac{P}{A}, i, 3\right) = 0$$

$$\left(\frac{P}{A}, i, 3\right) = \frac{24{,}680}{12{,}000} = 2.05667 = \frac{(1+i)^3 - 1}{i(1+i)^3}$$

$$i_{old} = 21.5\%$$

Example 6 (continued)

Iterative Solution

$$NPW_{new} = -73{,}570 + 26{,}000\left(\frac{P}{A}, i, 6\right) = 0$$

$$\left(\frac{P}{A}, i, 6\right) = \frac{73{,}570}{26{,}000} = 2.82962 = \frac{(1+i)^6 - 1}{i(1+i)^6} \Rightarrow \boxed{i_{new} = \frac{(1+i)^6 - 1}{2.82962(1+i)^6}}$$

$$NPW_{new} = -24{,}680 + 12{,}000\left(\frac{P}{A}, i, 3\right) = 0$$

$$\left(\frac{P}{A}, i, 6\right) = \frac{24{,}680}{12{,}000} = 2.05667 = \frac{(1+i)^3 - 1}{i(1+i)^3} \Rightarrow \boxed{i_{old} = \frac{(1+i)^3 - 1}{2.05667(1+i)^3}}$$

Example 6 (continued)

Iterative Solution

$$i_{new} = \frac{(1+i)^6 - 1}{2.82962(1+i)^6}$$

i	NPW_{new}
0.200	12893
0.235	5877
0.254	2498
0.262	1027
0.266	416
0.268	168
0.268	67
0.268	27
0.269	11
0.269	4
0.269	2
0.269	1
0.269	0
0.269	0
0.269	0
0.269	0
0.269	0
0.269	0
0.269	0
0.269	0
0.269	0
0.269	0
0.269	0
0.269	0
0.269	0

$$i_{new} = 26.9\%$$

i	NPWold
0.150	2719
0.167	1985
0.180	1415
0.190	990
0.198	683
0.203	466
0.207	316
0.210	214
0.212	144
0.213	97
0.214	65
0.214	43
0.215	29
0.215	19
0.215	13
0.215	9
0.215	6
0.215	4
0.215	3
0.215	2
0.215	1
0.215	1
0.215	1
0.215	0
0.215	0

$$i_{old} = \frac{(1+i)^3 - 1}{2.05667(1+i)^3}$$

$$i_{new} = 21.5\%$$

Example 6 (continued)

If MARR is 20%

Then, the new tractor is selected.

Rate of Return (ROR) Analysis

- If we assume the salvage value for the new tractor to be \$30,000 after 3 years, the NPW_{new} will be:

  $NPW_{old} = -24,680 + 12,000(P/A,i,3) = 0$

  i_{old} = <u>21.5%</u>

  $NPW_{new} = -73,570 + 26,000(P/A,i,3) + 30,000(P/F,i,3) = 0$

  i_{new} = <u>18.9%</u>

  Before the decision can be reached
  YOU MUST KNOW YOUR MARR.

- If MARR = 20% and 3 year analysis period, we choose <u>old tractor</u>.
- If MARR = 30%, we choose neither tractor - <u>do nothing</u> alternative.
- If the MARR were 15%, which alternative should we select then?

Rate of Return (ROR) Analysis

- Both NPW_{old} and NPW_{new} *exceed* the MARR = 15%.
- But since the old tractor yields a higher MARR, should it not be selected?
- To answer this question, determine each alternative's net present worth at 15%.

  NPW_{old} = -24,680 + 12,000(P/A,15,3) = \$2,719

  NPW_{new} = - 73,570 + 26,000(P/**A**,15,3) + 30,000(P/**F**,15,3) = \$5,519

  According to the above NPW analysis, the new tractor yields a higher value for a MARR of 15%?

  Shouldn't the alternative with the higher rate of return would yield the higher NPW regardless of the assumed interest rate?

  NO IT SHOULD NOT!

  The initial investments in the tractor examples we used are *not the same*.

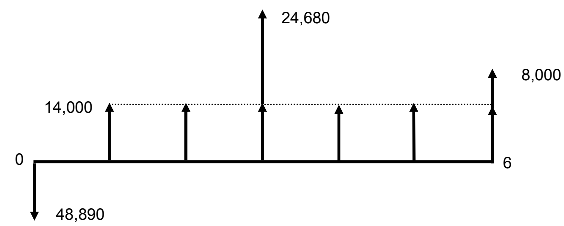
Incremental Rate of Return (ROR) Analysis

- When we examined the rate of return of each alternative, we have ignored their respective differences in initial cash flows. Therefore, we can obtain misleading results through such an analysis.
- To deal with the problem of unequal initial investments, *an incremental rate of return (IROR) analysis* is required.
- "For alternatives that have a satisfactory rate of return (ROR), what is the IROR of the difference in the cash flows of the alternatives?"
- To make this analysis, first arrange the alternatives in ascending order of initial cash flow. Then compare alternatives, two by two, alternatively rejecting the alternative with the lower IROR.

Incremental Rate of Return (ROR) Analysis

$$NPW_{new\text{-}old} = -\ 48{,}890 + 14{,}000(P/A,i,6) + 24{,}680(P/F,i,3) + 8{,}000(P/F,i,6) = 0$$

i = 30.9%



Incremental Rate of Return (ROR) Analysis

- While the initial investment of $24,680 for the old tractor will yield a ROR of 21.5%, the incremental increase in initial investment of $48,890 (by purchasing the new tractor) will yield an IROR of 30.9%.
- Now that all the rates of return are known, a decision can be reached *which is dependent on the MARR.*
  - For a MARR of 20% the ROR of the new tractor is too low, and therefore the old tractor is chosen.
  - For a MARR of 15% both alternatives exceed it and we have to examine the IROR.
  - In this case the IROR is higher than the MARR, so we should choose the new tractor.